Status of ProtoDUNE-DP light data publication

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ProtoDUNE-DP light data publication

- Title: TBD
  Long-drift scintillation light detection with ProtoDUNE-DP liquid argon TPC at CERN

- Table of contents ->

- Overleaf:
  https://www.overleaf.com/read/hxnzndpdmbpk

- Analysis carried out by J. Soto and A. Gallego, full details in previous meetings (only outline here)

1. Introduction

- DUNE
- ProtoDUNE-DP
- LAr scintillation light
- ProtoDUNE-DP Photon Detection System
- ProtoDUNE-DP operation

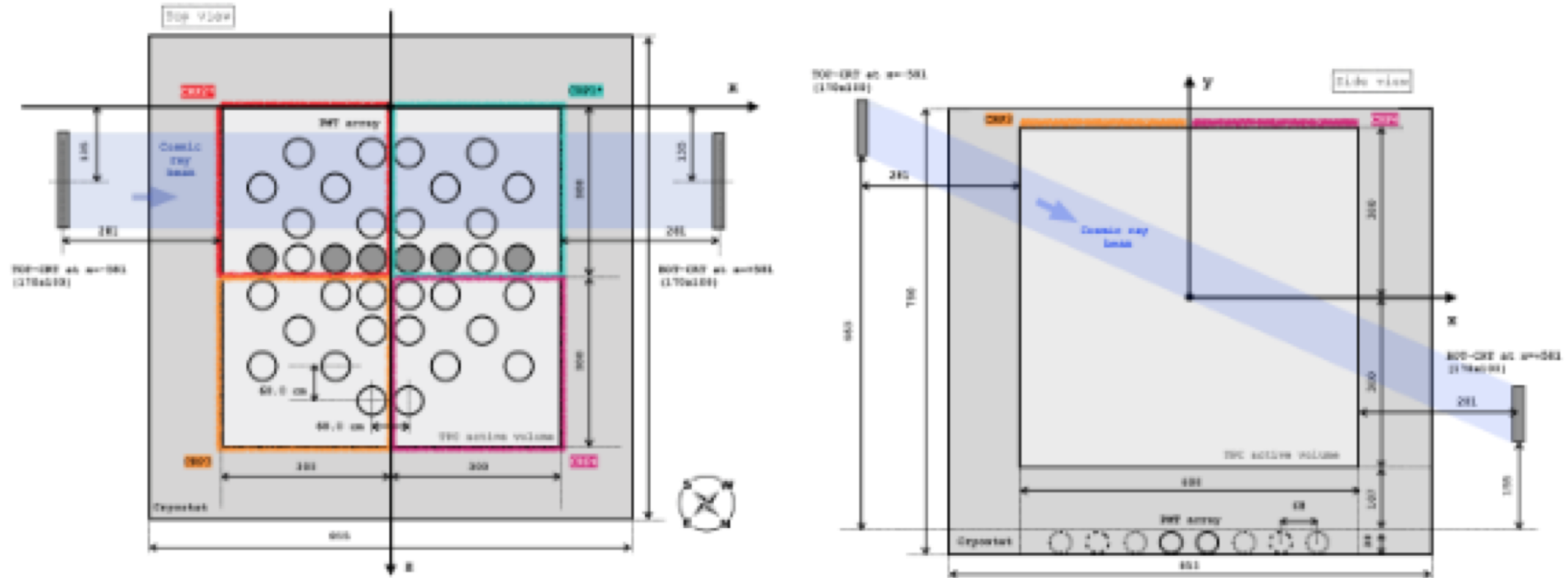~ 1.5 pages

1. Introduction

Photo?
Add PMT numbers (1-36)

Fig. 1 Views of ProtoDUNE-DP. Dimensions and positions of the major elements are indicated (all in cm units). The CRPs labeled as 1 and 2 are instrumented, while the frames labeled as 3 and 4 are not. The PMTs are represented with circles and, in the top view, the empty ones correspond to PEN PMTs and the filled circles to TPB PMTs.
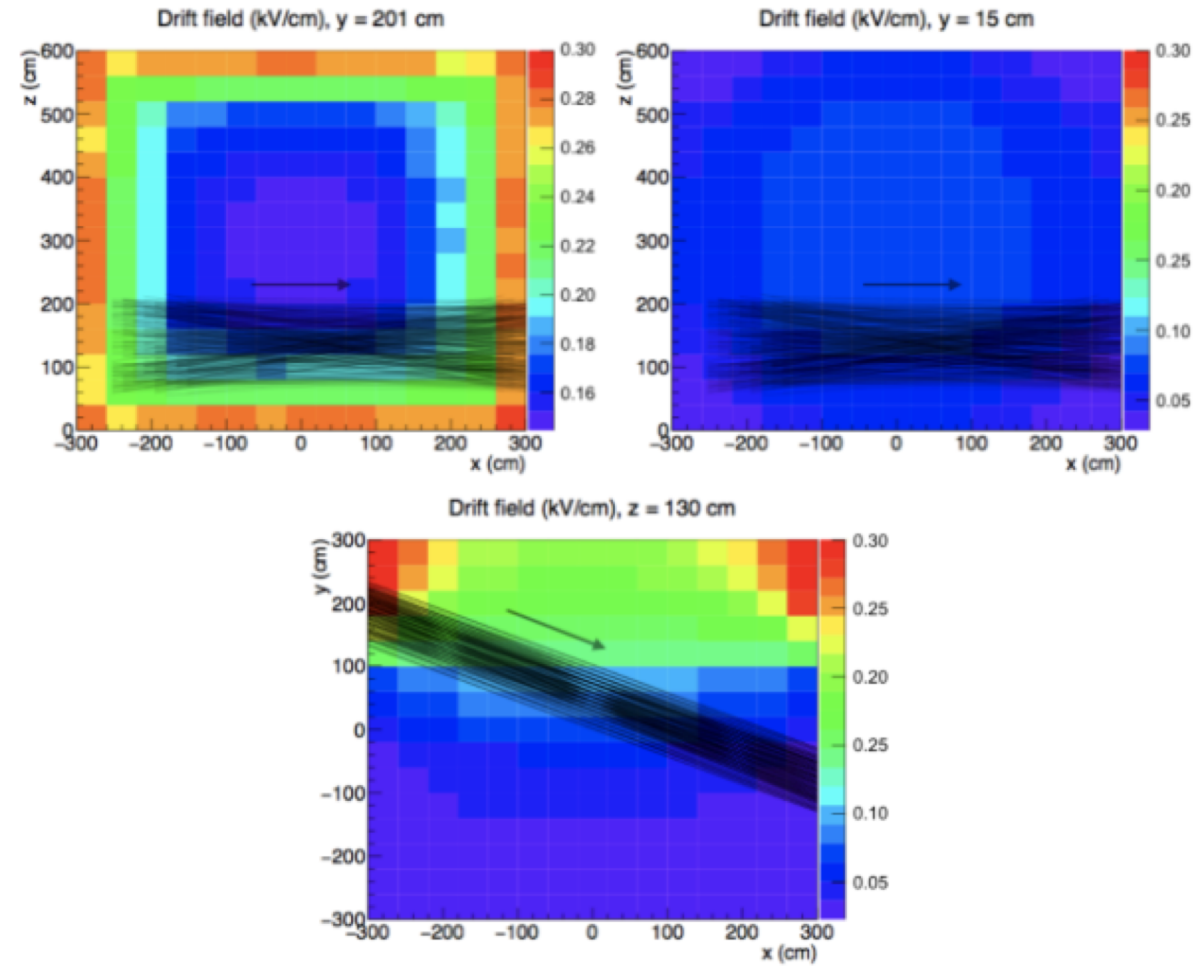
1. Introduction

Fig. 2 Maps of the drift field in ProtoDUNE-DP with cathode at -50 kV. Three particular planes of the active volume are shown. The drift direction is along the y-axis and the color scale is the electric field strength. The CRT-trigger muon-track projections into each plane are represented with black lines over the field maps.

2. Data taken with the ProtoDUNE-DP PDS at CERN

- Data taking overview

- Trigger modes

- Light DAQ

- Data taking conditions

- Light data in numbers

Show a waveform as an example here?

We usually show these tables, but rather adapt them to the data analyzed in the paper

TRIGGER	# of runs	# of events	Time (h)
CRT Panels	68	475 k	388
Random trigger	121	14 M	13
Calibration runs	1,208	28 M	37
PMT trigger runs	707	82 M	93
Random trigger with charge DAQ in coincidence	16	304 k	9
TOTAL	2,120	125 M	539

Table 1.   Number of events, runs and time of data taken in the different trigger configurations

DRIFT STATUS	LEMs VOLTAGE	# of runs	# of events	Time (h)
Drift OFF	0 kV	1,166	68 M	164
Drift OFF	2.5 - 3.0 kV	76	4.3 M	19
Drift OFF	3.1 – 3.6 kV	135	6.6 M	78
Drift ON	0 kV	131	13 M	29
Drift ON	2.5 – 3.0 kV	58	2.1 M	20
Drift ON	3.1 – 3.4 kV	240	6.6 M	190
Test and not stable	-	314	23 M	39
TOTAL	-	2,120	125 M	539

Table 2.   Number of events, runs and time of data taken with different voltage across LEMs.

~ 1 page

3. Simulation

- 3.1 Event generators: CORSIKA and CRT-gen
- 3.2 Light propagation: Rayleigh scattering length, photon libraries
- 3.3 PDS response: geometry, reflectivity, WLS efficiency, DC, noise
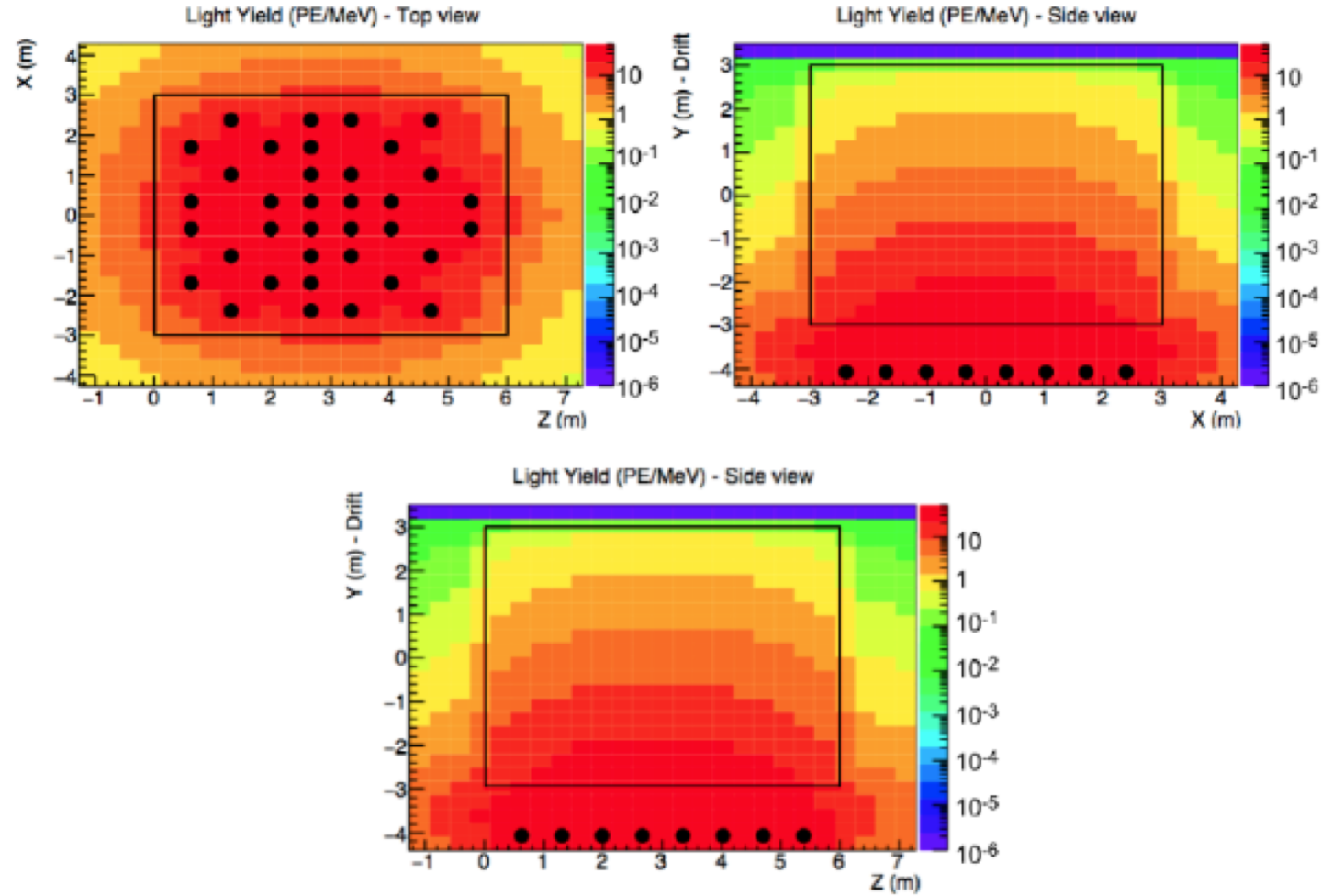
~ 2 pages

3. Simulation

Fig. 3 Light yield maps of the baseline photon library in ProtoDUNE-DP. 40k photons per MeV, 99.9 cm of Rayleigh Scattering length and VUV-reflections are assumed. The PMT positions are represented with black dots and the active volume with a black-border rectangle.

4. ProtoDUNE-DP PDS Performance

- 4.1 Calibration
- 4.2 SPE Characterization
- 4.3 Timing information
- 4.4 Wavelength shifting: PEN/TPB
- 4.5 System limitations
- 4.6 τ_{slow} as indicator of LAr purity

4.1 Calibration

- Goal

- Calibration system

- Calibration procedure

- Error

- Stability

- Reference calibrations and gain correction

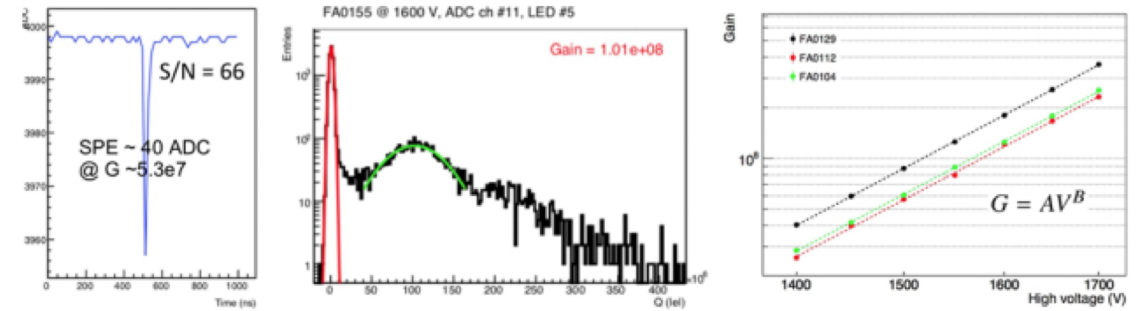We usually show these plots, but rather not add plots in this section

Figure 26   Left: Calibration pulse (SPE) in the PMT waveform. Center: SPE spectrum for one PMT fitted to two Gaussian functions. Right: Gain as a function of the HV for 3 PMTs (fitted to a power law).
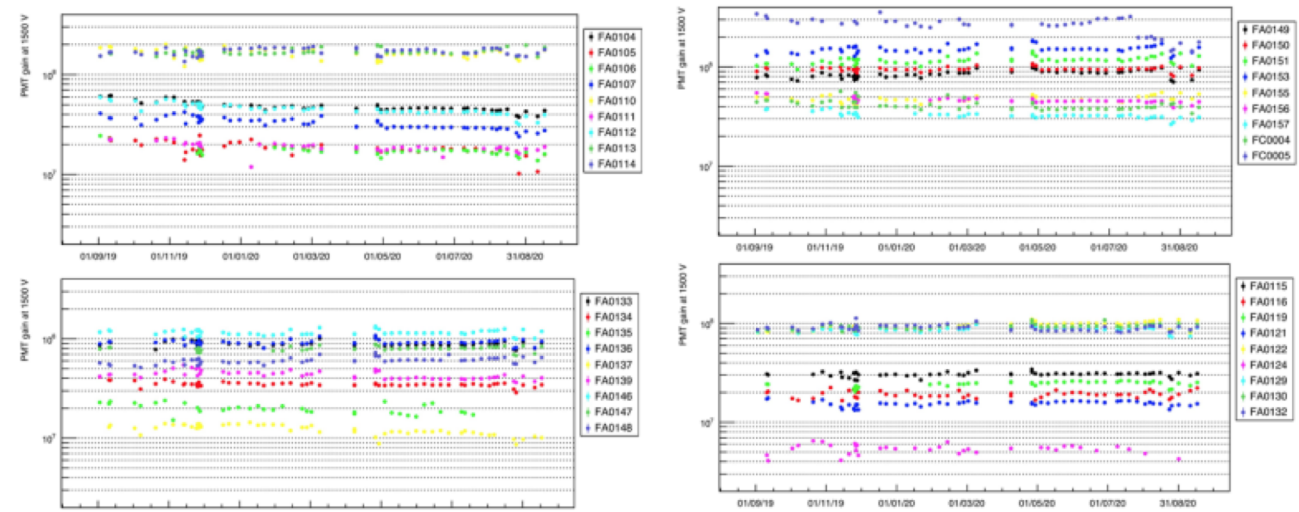

re 27   Gain stability with time at 1500 V for the 36 PMTs during one year.

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4.2 SPE Characterization
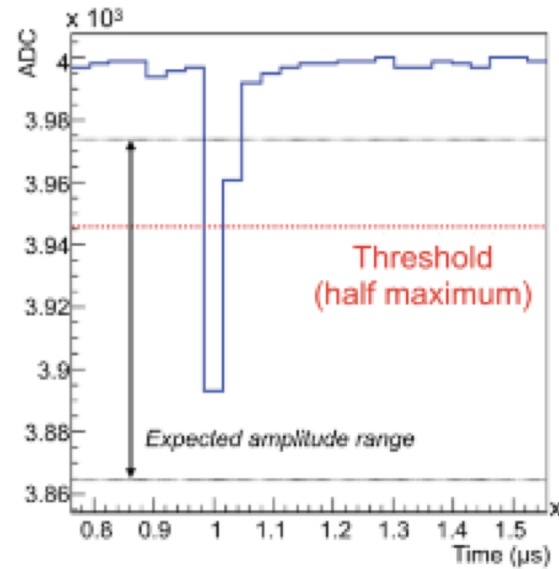
- SPE amplitude
- SPE rate
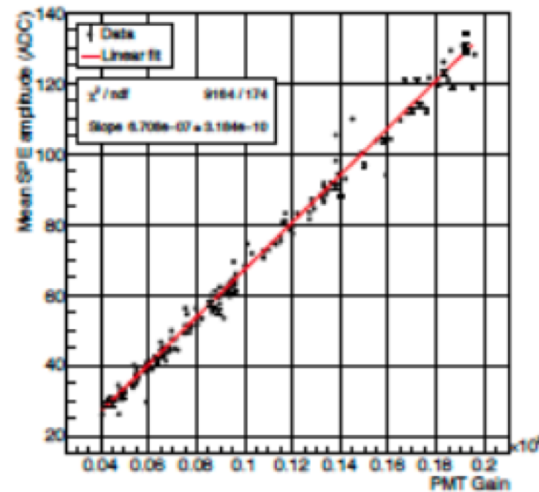

Fig. 4 Example of SPE.

Fig. 5 Mean SPE amplitude from Gaussian fits as functions of the PMT gain, and linear fits.
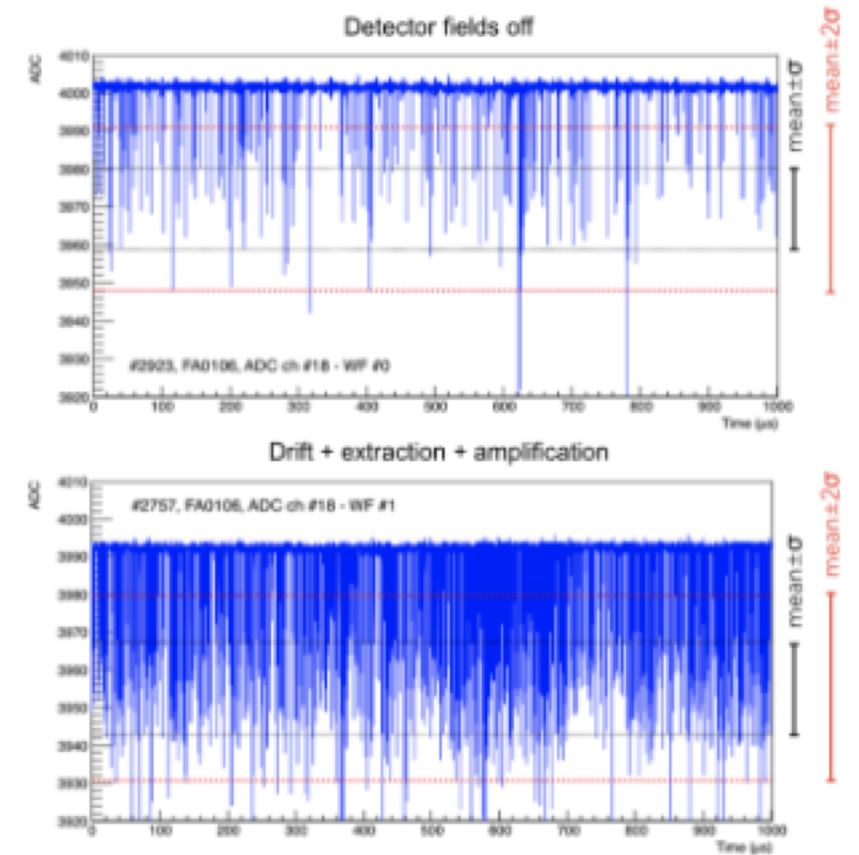

Fig. 6 PEN PMT waveforms ($5 \cdot 10^7$ gain) acquired in random-trigger mode. Top panel: Run with detector fields off. Bottom panel: Run with drift (cathode at -50 kV), extraction (grids at 6.0-6.2 kV) and amplification (LEMs at 3.1-3.4kV across) fields. A zoom in the y-axis is set to focus on the SPE signals.

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4.3 Timing information

- Requirement
- Sources of time misalignment
- Data description
- Data processing and selection
- Results

t and σ distribution for all PMTs.

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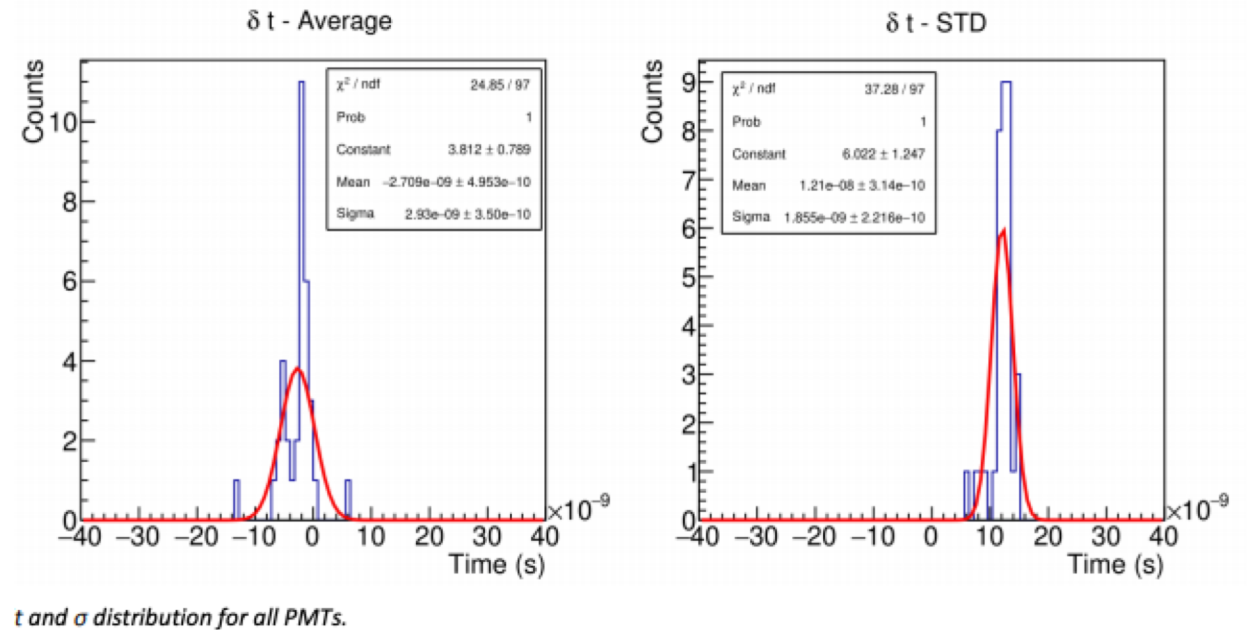
4.4 Wavelength shifting PEN/TPB

- PEN & TPB description
- TPB-PMTs efficiency

$$E_{TPB} = E_{TPB,RT} \cdot \delta_{TPB,CT} = 0.154 \pm 0.022$$

- TPB Efficiency

$$\epsilon_{TPB} = \frac{E_{TPB}}{\Delta_{coat} \cdot QE} = 1.71 \pm 0.024$$

- PEN efficiency

$$\epsilon_{PEN} = \frac{NPE_{PEN}}{NPE_{TPB}} \cdot \frac{\gamma_{coat}}{\gamma_{foil}} \cdot \frac{\Delta_{coat}}{\Delta_{foil}} \cdot \epsilon_{TPB} = 0.53 \pm 0.18$$

- PEN-PEMTs efficiency

$$E_{PEN} = \epsilon_{PEN} \cdot \Delta_{foil} \cdot QE = 0.023 \pm 0.007$$

PEN/TPB comparison to be detailed in a dedicated publication, main goal here is to estimate TPB-PMTs and PEN-PMTs efficiency to be used in the simulations and compare with data
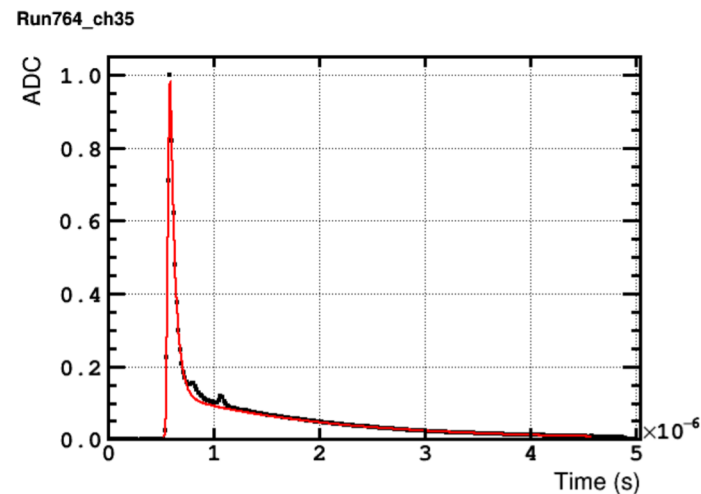
TPB efficiency over-estimated, proposed alternative, consider it 100%, and estimate TPB-PMTs and PEN-PMTs efficiency accordingly

No plots proposed in this section

~ 2 pages

4.5 System limitations

- S/N ratio

- PMT linear operation range

- 11 PMTs with early saturation

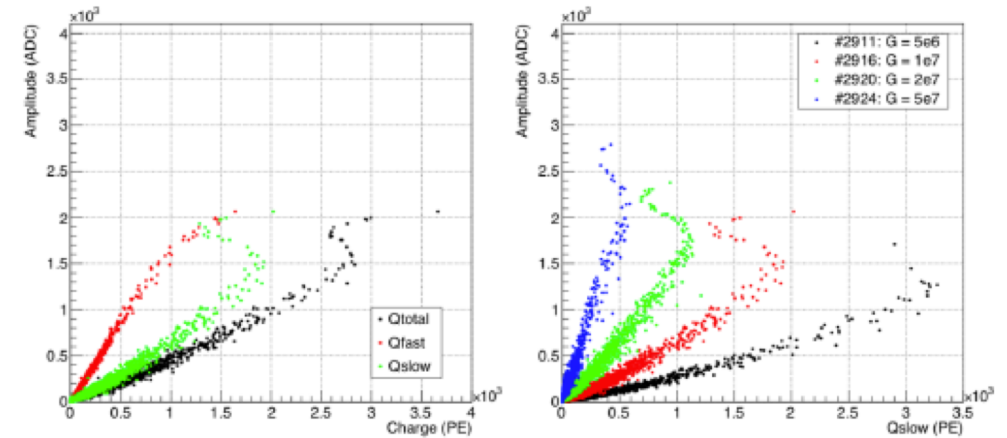Signal reflections? If relevant in the following

Plots?

FIGURE 3.18: Amplitude vs. charge for a PEN PMT (FC0004). Left: Comparison of different integration windows ($1 \cdot 10^7$ gain, run #2916). Right: Comparison of different gains for Q_{slow}.
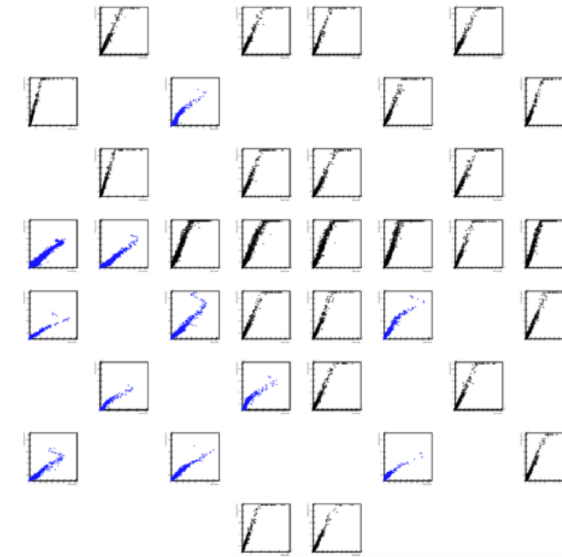

FIGURE 3.17: Amplitude (ADC) vs. Q_{slow} (PE) for the 36 PMTs ($5 \cdot 10^7$ gain, run #2924). Each plot corresponds to one PMT and they are displayed according to their positions in the detector. PMTs showing a linear amplitude-charge correlation in all the ADC range are in black and PMTs presenting early saturation and/or non-linear behaviour are in blue. The vertical scale (amplitude) is the same (0-4100 ADC) in all the plots while the horizontal scale (charge) is different (up to a few thousands of PE) so the shape of all the distributions can be observed.

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4.6 τ_{slow} as indicator of LAr purity

- Add it as a section?
- Fitting description and plot
- Add plot and/or average?
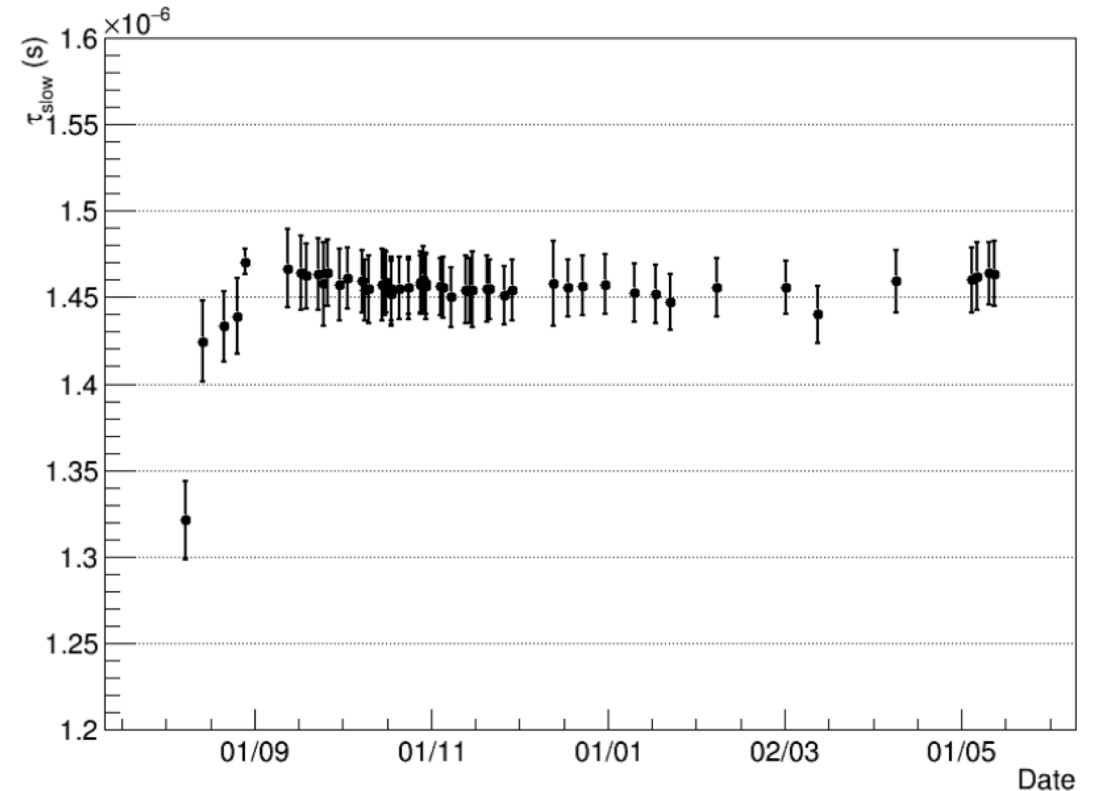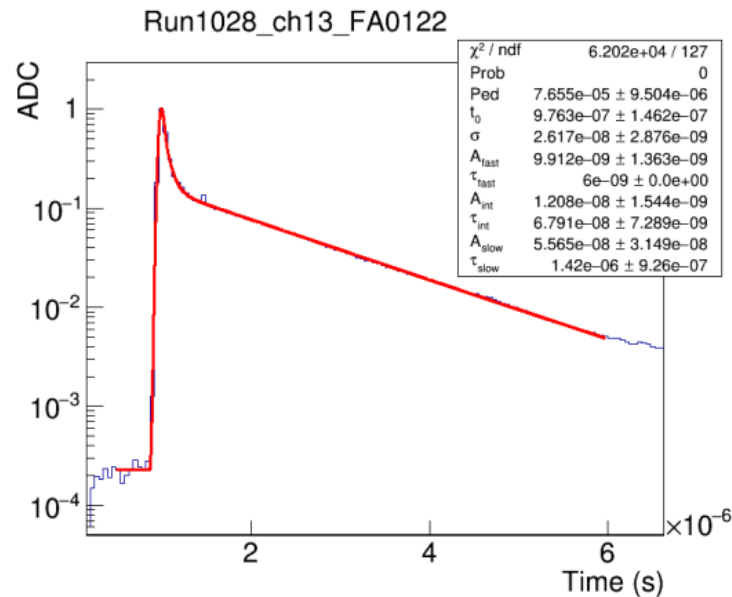
5. Study of light production and propagation inLAr with cosmic muon tracks

- Data and simulation description
- Event selection
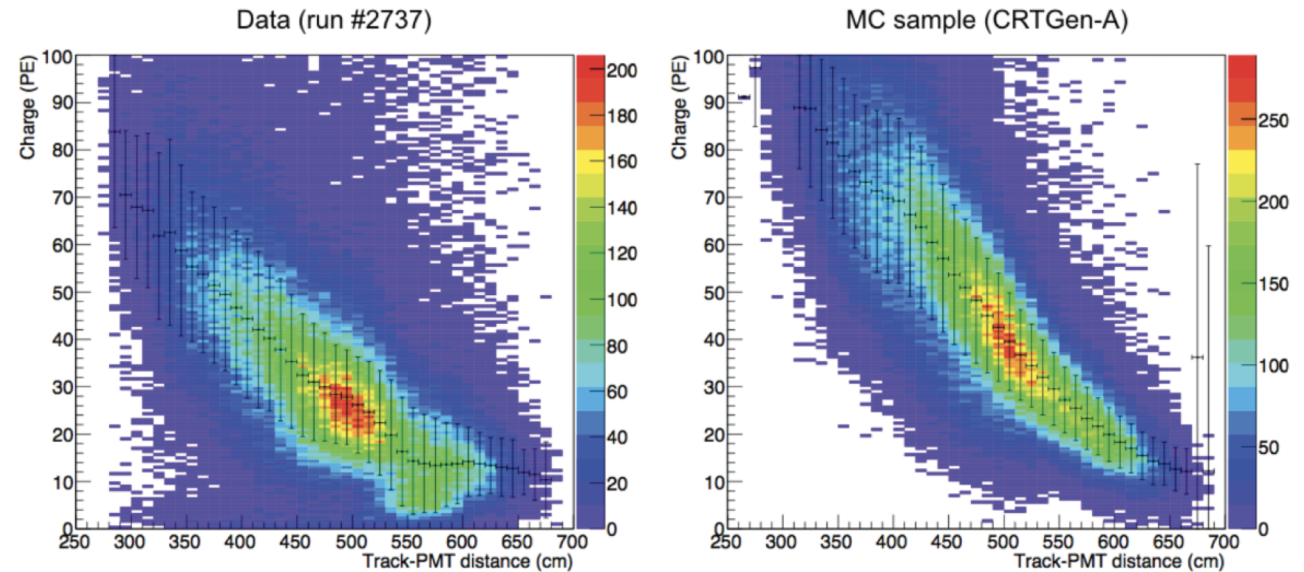- Data/MC comparison

Proposal: focus on PEN and omit PEN

Fig. 8 Collected S1 charge versus track-PMT distance for PEN PMTs: data (left) and MC sample (right). The color maps contain all the S1 signals detected by the PMTs and passing the event selection. A Gaussian fit of each charge-distribution every 10 cm is performed and the results (mean values) are plotted in black over the map. The vertical error bars correspond to 1‡ from the fits and a 5-cm distance uncertainty (horizontal error bars) is included.

5. Study of light production and propagation inLAr with cosmic muon tracks

- Data and simulation description
- Event selection
- Data/MC comparison

TPB efficiency over-estimated, proposed alternative, consider it 100%, and estimate TPB-PMTs and PEN-PMTs efficiency accordingly
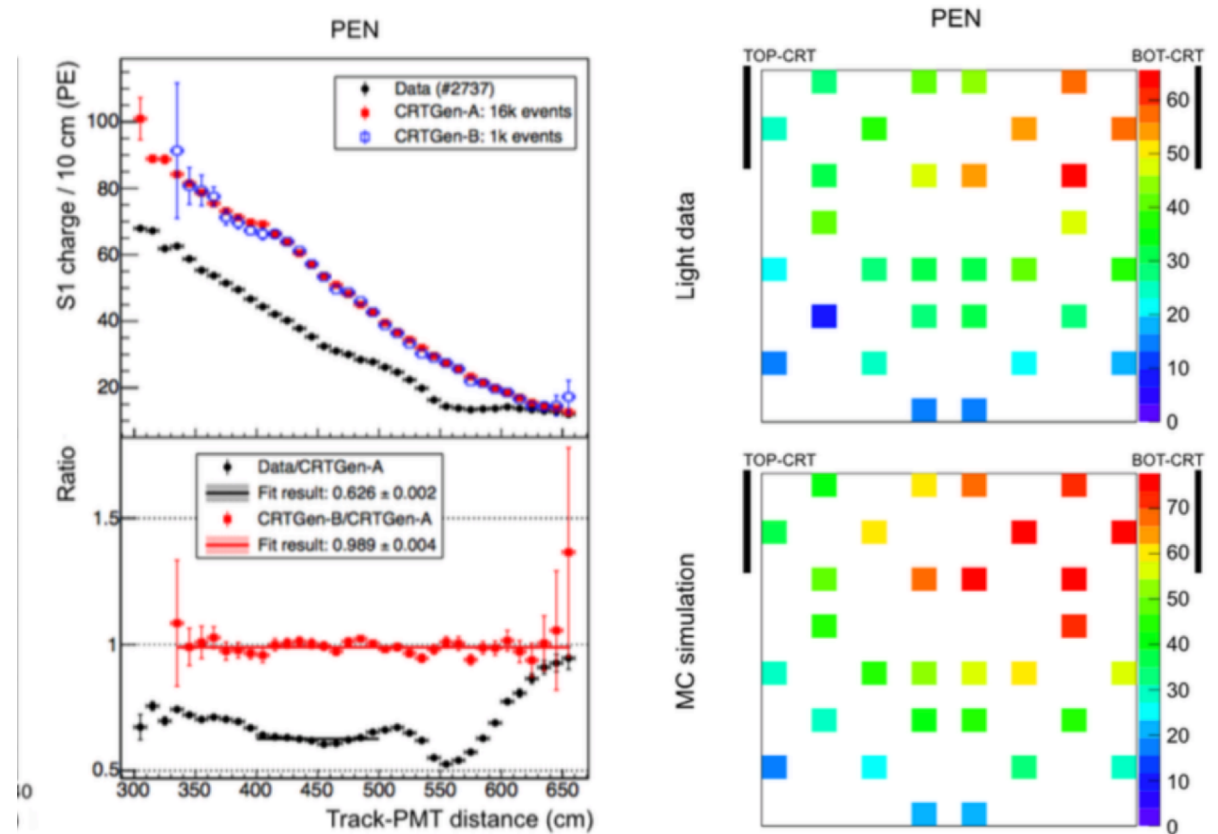
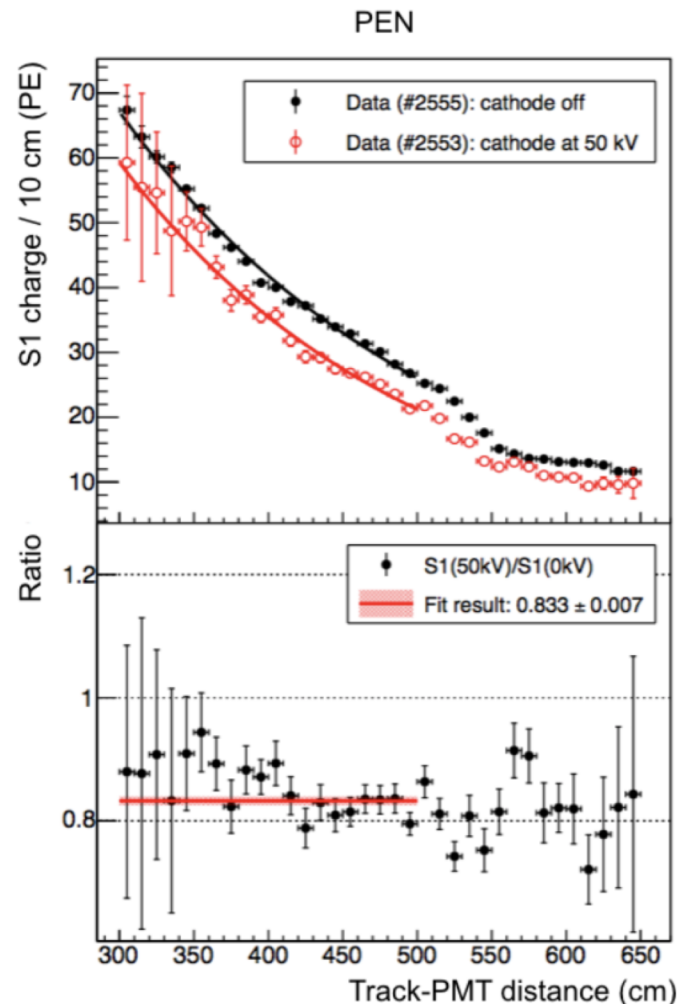# 5.1 Light production: Light yield suppression with drift field

PEN

Fig. 9 Top panel: Average collected S1 charge as a function of the track-PMT distance for PEN PMTs. Two data runs are compared: with null drift field in black and with cathode at -50 kV in red. Each data sample is fitted to an exponential function in the distance range without response saturation (up to 500 cm); the fit is plotted as a solid line (values in Table ??). Bottom panel: ratio between the S1 response with drift field and the one without. The ratio distribution is fitted to a constant value (results in legends and in Table ??). The 300-500-cm range is considered for the fits.
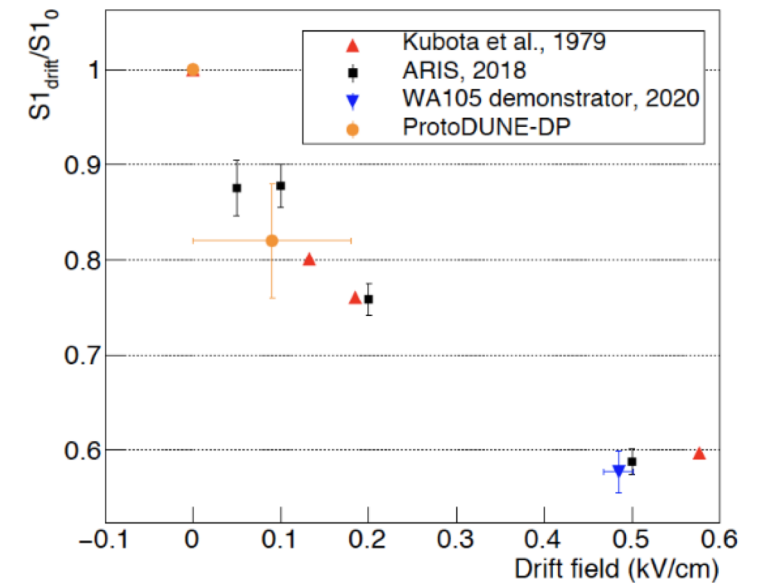

Fig. 10 Light yield reduction with drift field measured by different experiments (red triangles from ??, black squares from [69], and blue inverted triangles from ??), including the ProtoDUNE-DP result (orange circles) discussed in this section.

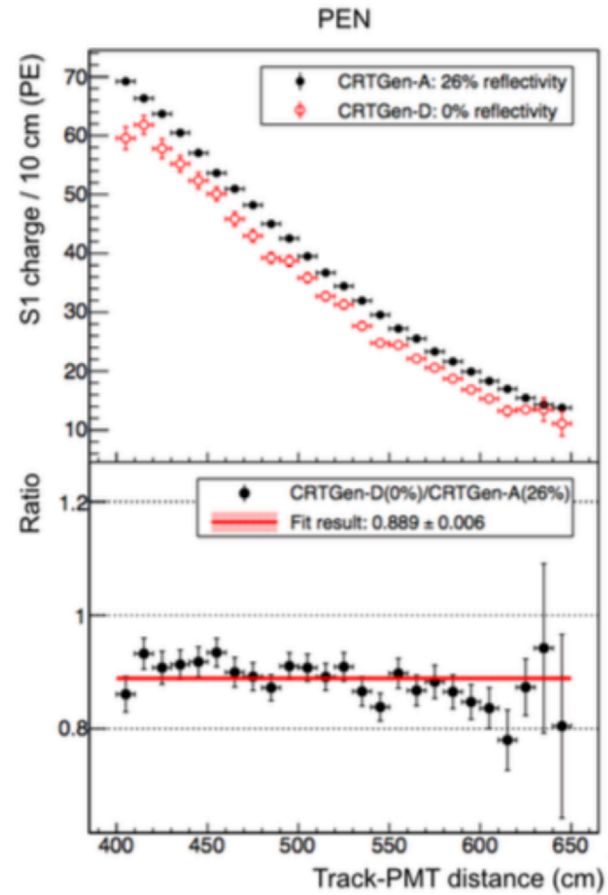Add also effect on t_{slow} and normalization constants?

5.2 Rayleigh scattering length

99.9 cm vs 61 cm comparison

PMT WLS	Run/sample	RSL* (cm)	Q-vs-d exp. fit $\exp(-\lambda_{Att} \cdot d + C)$ $1/\lambda_{Att}$ (cm)
TPB	Data (#2743)	–	182 ± 18
	CRTGen-A	99.9	175 ± 10
	CRTGen-C	61.0	143 ± 17
PEN	Data (#2737)	–	180 ± 18
	CRTGen-A	99.9	181 ± 10
	CRTGen-C	61.0	159 ± 11
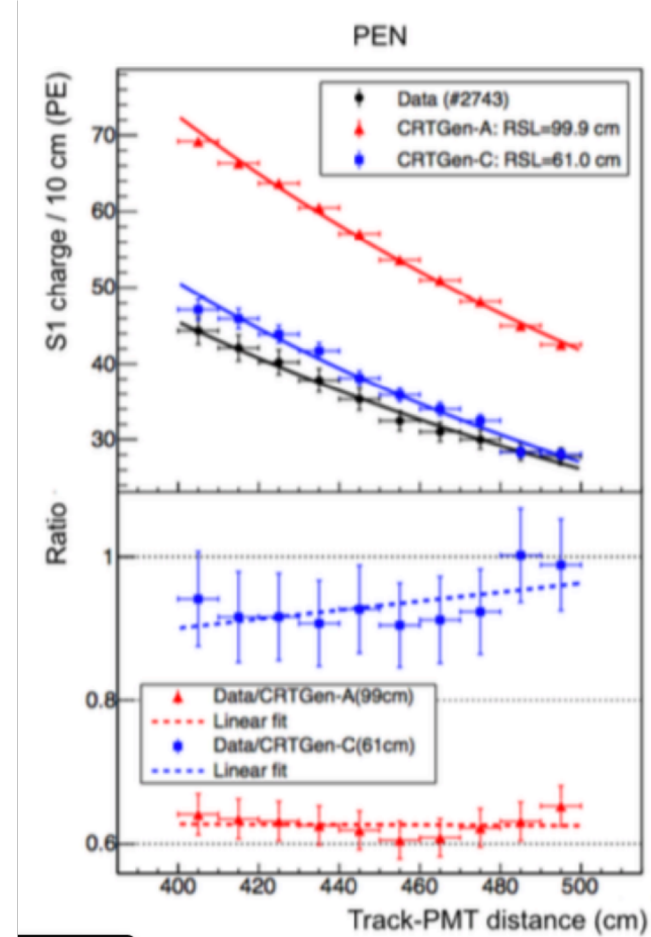
5.3 Impact of VUV reflected light

5.4 PMT efficiency analysis

- Compare different TPB efficiencies?

6. Cosmic muon flux measured in ProtoDUNE-DP operating at CERN

- S1 rate correlated and uncorrelated
- Muon flux result

7. Electroluminescence light detection

- Data description
- S2 finding algorithm
- If possible measure drift time or drift velocity

8. Xe doping

- Full analysis will be a different publication, what to include here?